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Learning from 20 Years of Research on Innovation Economics

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About the Author

Bruno van Pottelsberghe has been Dean of the Solvay Brussels School of Economics and Management (SBS-EM), at Université libre de Bruxelles (ULB) since April 2011 to September 2017. He is Full Professor and, as holder of the Solvay SA Chair of Innovation, he teaches courses on the economics and management of innovation and intellectual property. His research, which focuses on patent systems, the valuation of patents, and science and technology policies, has been published in several international scientific journals, including *Research Policy*, *Journal of Public Economics*, *Review of Economics and Statistics*, and *Industrial and Corporate Change.* His research is essentially applied and has the particularity of being frequently inspired by his professional experience. Papers on academic patenting and technology transfer offices were inspired by his position as chair of the ULB's Technology Transfer Committee since 2004. The papers on patent systems were stirred by his experience as Chief Economist of the European Patent Office in Munich, from 2005 to 2007. The papers on the effectiveness of science and technology policies were triggered by his professional experience at the OECD Directorate for Science, Technology and Industry (DSTI) in Paris, from 1997 to 1999. His work on international and interindustry R&D spillovers was ignited by his visiting research position at the Research Institute of the Ministry of External Trade and Industry Research Institute (METI/RI) in Tokyo in 1995. Bruno van Pottelsberghe held Visiting Professor/Researcher positions at Columbia University (NYC, 1996), Stellenbosch University (Cape Town, 2003), Hitotsubashi University (Tokyo, 2003). As Dean of the SBS-EM he initiated and chairs the QTEM Master network (Quantitative Techniques for Economics and Management), a global network of universities and companies focusing on analytical techniques applied to economics and business.

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Introductory Chapter:

Learning from 20 Years of Research on Innovation Economics

1. Introduction

This introductory chapter summarizes 20 years of research activities, which started at Université libre de Bruxelles (ULB) with a four-year scholarship in 1992. These years are tainted by a focus on empirical research, by intensive local and international collaborations, and by a series of field experiences which became key sources of inspiration and gradually improved the contextualization of the research projects I was involved with.

The broad research contributions I have been involved with are twofold: I started with the effectiveness of science and technology policies, and then focused on the effectiveness of patent systems. Effectiveness has two meanings. The first one is related to the systematic search for improvement, the constant questioning of status quo, of existing policies, with the identification of their strengths and weaknesses. The second meaning of effectiveness is related to the improvement of data and metrics needed to properly analyze policy tools, and the search for more appropriate indicators. The papers presented in this book all aim at improving metrics and using new data and indicators in order to contribute to improve our knowledge on whether and how policy tools work.

The effectiveness of science and technology policies is assessed through their impact on research and development (R&D) efforts and on growth prospects. We have investigated to what extent and under which circumstances R&D subsidies and R&D tax credits stimulate private R&D and contribute to productivity growth. The effectiveness of patent systems is assessed through the lenses of their costs, their operational design, their transparency and the stringency of the examination processes.

The outcome of these 20 years of research includes about 60 publications in international peer reviewed scientific journals and one co-authored book published by Oxford University Press. Each of these publications was a small challenge, at least the way I perceived it. We had to reach a final version, present it at conferences, submit it for publication, cope with sometimes tough referees, dive again into the paper more than a year later and implement the required changes, and re-submit it with a polite letter to the referees and the editor.

The main common denominator I would chose to summarize my research experience is 'mobility', defined in its broadest sense: mobility or flexibility with respect to career expectations, with respect to internationalization, with respect to institutional experience, and with respect to collaborations. The sources of inspiration of most papers were nearly systematically drawn from my professional experience. For instance, the priority issues that had to be tackled by the Research Institute of the Ministry of External Trade and Industry (METI) when I was visiting researcher, the benchmarking exercises requested by the Organisation for Economic Co-operation and Development (OECD) task forces when I was full-time consultant in Paris, and several debates which took place at the board of the European Patent Office when I was its Chief Economist had a direct influence on the research projects I later worked on.

The book is structured around seven main themes, each of which includes two to five papers published between 1998 and 2016. The full list of published papers is available in the reference list of this introductory chapter, as only 29 papers could be reproduced in this compendium. The next section provides a more detailed chronological perspective of my research experience over the past 20 years. The four dimensions of 'mobility' are outlined before the presentation of each broad research theme.

2. Chronological Perspective: The Role of 'Mobility'

This section provides a brief summary of the various chronological milestones that marked the past 20 years of my research and professional experience. This journey all too amply illustrates the importance of 'mobility'. The term 'mobility' is defined in several ways, including personal expectations, international reach, institutional employers and collaborators.

My research experience actually started with a mobility or flexibility about my ***career expectations***. The main objective at the end of my master degree in Economics at ULB was to work for the private sector. And before I started acting towards the labour market and identifying which companies I would target, one of my professors, Henri Capron, asked me if I wanted to make a Ph.D. under his supervision. He had obtained a two-year ULB scholarship that could be renewed once. I had never envisaged such an opportunity. True, during my studies I enjoyed — and performed well — group works and individual assignments like the end-year thesis, but I was not the 'best in class'. I accepted the offer, not without a cautious mindset and far from being confident I would ever finish this dissertation, or that I would pursue the research experience for four years. I was not convinced to be sufficiently skilled, and, first and foremost, doing a Ph.D. had never crossed my mind.

The second dimension of mobility is related to the ***international experience***. As briefly sketched here, I performed part of my research at prestigious institutions in the US and in Japan, working with senior researchers. I have lost the initial letters I sent in 1994, but what I appreciate for sure now is their open mind: they accepted to collaborate with me despite the fact that I had literally no publications in my track record. These very productive and positive experiences abroad (both for my research and my personal experience) were important stepping stones of my scientific and international career.

The third dimension of mobility is ***institutional***. I truly benefitted from several experiences in national or international institutions, which somewhat drove the lion's share of my research output: being policy relevant, and inspired by field experience or contemporaneous policy challenges. The best illustration probably comes from the experience as Chief conomist of the European Patent Office, which definitely inspired the subsequent years of research, up to now. This dimension is particularly important for modern academic research, which can benefit to and be inspired by actual policy or managerial challenges. Being exposed professionally by these challenges was a very important source of inspiration for most of my research projects.

The fourth dimension of mobility, probably the most important one, is related to a ***collaborative*** mindset. The vast majority of my research output is collaborative in its nature. I started with senior professors and scholars, including Professor Henri Capron (ULB), Professor Hiroyuki Odagiri (then at METI and Tsukuba University), Professor Frank Lichtenberg (Columbia University), and Dominique Guellec (then Head of Statistical Unit at OECD Directorate for Science, Technology and Industry). As I went back to academia, I pursued an intensive international and local collaboration. I had the pleasure to collaborate with more than 10 international scholars, most of them being professors in universities abroad. Over the years this collaboration also took place with more junior researchers, including researchers, 11 Ph.D. scholars I advised, and several end-year Master students. Several papers presented in this book are indeed the fruit of collaborative work with Ph.D. candidates I supervised, including Carine Peeters, Ant Bozkaya, Nicolas van Zeebroeck, and Gaetan de Rassenfosse, amongst the six who later pursued an academic career. Five papers reproduced in this book have actually been performed jointly with Master students working on their end-year thesis (Mathis de Saint-George, Didier François, Florence Honoré, Ran Navon, and Sarina Saragossi). Be it with senior or junior researchers, collaborative research projects are always more creative and productive, as the pair jointly benefit from intense intellectual debates and creative brainstorms, not to mention complementary skills.

2.1. *Starting with a Research Scholarship at ULB, 1992–1997*

I started my research activities thanks to a 2-year ULB Ph.D. scholarship (so-called mini-arc) in September 1992, which could be renewed once. The project took place in the Department of Applied Economics of ULB (DULBEA), and the broad area of investigation was related to the economics of innovation. My advisor, Professor Henri Capron, stimulated me to adopt an empirical approach. He systematically requested to develop the policy or managerial implications of my research projects. The Ph.D. program included a compulsory Master degree in Econometrics (which would later become the research master of the ECARES Ph.D. program). This master was key to acquire advanced research skills. After two years of studies and research I became motivated to complete the Ph.D., for two reasons. First, I succeeded particularly well in the master degree, especially the individual seminars, which gave me some self-confidence. Second, I had sent four letters to professors specialized in my field — two in Japan and two in the US — asking them whether we could collaborate for six months. The idea was to better understand other countries' innovation systems, and get exposed to alternative research methods. I received one positive reply from each country. I suddenly had the opportunity to enter into effective international collaboration, and I dived into it.

2.2. *First Experience Abroad: METI/RI in Tokyo, 1995*

Professor Hiroyuki Odagiri (Tsukuba University) invited me to join him at the Research Institute of METI (the Ministry of External Trade and Industry, in Tokyo) in 1995. My research area first focused on inter-industry R&D spillovers, trying to measure the extent to which the research performed in one industry could positively impact the productivity of other industries. Then, I took part in their broad policy-oriented research area, which focused on foreign direct investment (FDI). I acquired knowledge on FDI flows and performed an in-depth state of the art of the studies aiming at measuring international R&D spillovers, or the extent to which the research performed in a country would contribute to the productivity growth of other countries. I was particularly inspired by the paper of Coe and Helpman (1996), who measured trade-related international R&D spillovers.

2.3. *Second Experience Abroad: Columbia University in NYC, 1996*

Professor Frank Lichtenberg (Columbia University) welcomed me in 1996 to work on a research project aiming at measuring FDI-related international R&D spillovers (or knowledge transfer). Our idea was to complement Coe and Helpman's (C&H) analysis by including Foreign Direct Investment (FDI, both outward and inward) in the empirical model. By trying to replicate C&H results, we noticed two methodological biases (related to indexation and to weighting schemes). First we developed a more appropriate methodology to measure the stock of foreign R&D (weights based on the R&D intensity of trade flows are much less biased than weights based on bilateral trade flows). We also showed that outward FDI have reverse spillover effects. I went back to Brussels in late 1996 and was a few months later recruited by the OECD/DSTI (Directorate for Science, Technology and Industry), and worked in the unit directed by Dominique Guellec. We started a long-lasting and very effective research collaboration.

2.4. *Third Experience Abroad: OECD/DSTI, Paris, 1997–1999*

My role at the OECD was to perform empirical analyses aiming at improving policy making. From my experience in DSTI, I learned how to really draw policy implications from stylized facts and empirical analyses. The contrast with classical academic research was interesting. Whereby academic research papers generally allocate one paragraph (maximum one page) to describe the policy implications of their results, an opposite approach was adopted by the OECD. The methodology consisted in describing the whole area of a given policy tool, performs international benchmarks, and relies on advanced academic research. The quantitative modelling was rather — and logically so — for the appendix. During my stay at the OECD I focused on R&D tax credits, R&D subsidies, and public R&D. The intense interaction with government officials — country delegations — was an interesting experience. These interactions actually inspired several research papers I worked on when

I came back to ULB. My stay at OECD also led me to discover the richness of raw patent databases. For instance, I had the chance to generate the first official patent-based statistics published by an international organization. The methodology that we created with Hélène Dernis and Dominique Guellec was later adopted by many international and national public institutions.

2.5. *Back to ULB, 1999–2005*

When I came back to ULB, as holder of the Solvay SA Chair of Innovation, I joined the Centre Emile Bernheim, which focuses on applied economics and management sciences. I worked intensely on two types of research tracks. The first one consisted in investigating empirically the effectiveness of various policy tools aiming at fostering economic growth and/or private R&D expenditures. The second one consisted in working with patent data for several research objectives: fine-tuning patent count methodologies in order to identify high-value patents; developing technological globalization indicators; and starting to investigate the role and value of academic patents. Whereas these research tracks were essentially driven by my experience at the OECD, the academic patenting research projects were actually motivated by field observation. Indeed, in the early 2000s I was appointed as Advisor to the President and the Rector of ULB, for knowledge transfer issues at the institutional level. Being the chairman of the knowledge valuation committee, I was exposed to several challenges associated with the actual transfer of knowledge, from academia to industry. This exposure led to new research ideas on academic patenting and the governance of knowledge transfer. This is the time I started research projects on academic patenting, academic spin-offs, the funding of technology-based firms and the impact and determinants of venture capital in Europe.

2.6. *Fourth Experience Abroad: European Patent Office, Munich, 2005–2007*

I was appointed as Chief Economist of the European Patent Office (EPO) from 2005 to 2007. The role of the Chief Economist was split between international representation of the EPO towards several stakeholders (industry, policy-makers, EPO leadership, examiners) and providing empirical evidence on several dimensions of patent systems. During my stay I was particularly interested in three broad issues that affected key stakeholders of the patent system: fees, quality, and the unitary patent (the former nickname of the community patent project). I noticed that patent fees were a highly sensitive issue, that looking at quality in examination services was not particularly welcome, and that promoting the community patent project was not politically correct. The fact that three topics were barely welcome by several stakeholders (i.e., patent attorneys, the leadership of several patent offices, some EPO departments, several companies), or that I even actually felt some resistance, was a real motivation to pursue my investigations in these topics. It was however more appropriate to work in a more appropriate environment, where I would be 100% free to pursue these research projects, with a complete freedom of judgement.

2.7. *Back to ULB and Bruegel, 2008–···*

In December 2007, I came back to ULB and joined as well the Bruegel Think Tank. At ULB I was part of the ECARES research center and spent four years of very intense research, with several fields under the radar, all of them being inspired by my experience as Chief Economist of the EPO: fees, quality and unitary patents. The period ranging from 2009 to 2013 was probably my most productive in terms of number of scientific publications per year and their visibility. I co-authored several scientific papers jointly with several professors and researchers and these papers received a wider visibility through the policy briefs and blueprint written for Bruegel, with a more applied and policy implication focus.

My research productivity gradually vanished from April 2011 onwards, when I was appointed as Dean of the Solvay Brussels School. I enthusiastically dived into this massive managerial task, which logically reduced the time I could allocated to research.

2.8. *Quality Assessment*

Looking backward to these 20 years of research, I cannot help thinking about the quality of these papers. Some were published in very good scientific journals, others in journals with easier access or higher publication probabilities. Some papers where highly cited, with several hundreds of cumulated Google citations, or heavily downloaded, while others are barely quoted or read. What is interesting is that there is no systematic correlation between these 'quality' indicators, and especially not with my own 'preferred' list of papers. For instance, one paper I was particularly proud of — and heavily cited — was eventually refused in a top level scientific journal, with only two sentences from a referee who was '*doubtful*' about the results, with no further details on what was potentially wrong. The opposite is also true, as one paper accepted in a very good scientific journal has actually received a relatively small number of citations.

3. Snapshot on Five Areas of Research

The five following subsections summarize the 29 chapters, grouped in seven Parts (Part I to Part VII). For the sake of conciseness and in order to avoid repetitions, I have twice grouped two parts in the subsequent snapshots. Patent metrics (Part II) and patent valuation models (Part III) are summarized together. Similarly, Part VI on the design of patent systems is summarized jointly with Part VII on the European patent system.

3.1. *On Science and Technology Policies, R&D Spillovers and Growth (Part I)*

Being visiting researcher at METI/RI (the Research Institute of the Ministry of External Trade and Industry, in Tokyo) in 1995, I took part in their broad policy-oriented research agenda, which focused partly on foreign direct investment (FDI). I started collecting data on FDI flows at that time, while performing a comprehensive state of the art of the literature on international knowledge transfer. I was particularly inspired by the working paper published by Coe and Helpman (NBER 1994, later published in 1996 in the *European Economic Review*) entitled "International R&D Spillovers". Coe and Helpman (C&H) measured the economic impact of these spillovers by relying on bilateral trade flows. I then went to Columbia University in NYC to collaborate with Professor Frank Lichtenberg. Our idea was to complement C&H's analysis by including FDIs (both outward and inward) in the empirical model. The research question was to investigate whether inward FDI and outward FDI (learning about foreign markets) are also embedded with significant international R&D spillovers.

For this research project, we started by trying to replicate the analysis based on trade flows. In doing so, we actually developed a more appropriate methodology than C&H to measure the stock of foreign R&D. We illustrated that data indexation can bias econometric estimates in a panel data framework. We also provided empirical evidence that weights based on the R&D intensity of trade flows are much less biased than weights based on bilateral trade flows. In other words, by attempting to replicate an existing analysis we identified rooms for improvement, which led to the publication of the first chapter paper of this book, by Lichtenberg and van Pottelsberghe (1998).

We then pursued with our willingness to measure whether inward and outward FDI also contribute to transfer knowledge internationally. By relying on a then unique data set of inward and outward FDIs, we performed an analysis similar than the one of C&H, but with another embodiment.

The results of this second analysis suggest that outward FDI have reverse spillover effects, allowing domestic firms to exploit foreign technologies when they invest abroad. Inward FDI do not seem to contribute — positively or negatively — to economic growth. This empirical evidence of the technology sourcing effect is reported in van Pottelsberghe and Lichtenberg (2001).

These two early papers illustrate the simultaneous impact of domestic and foreign R&D on growth. As research activities have since the 1970s been a strong focus of policy-makers, I started looking at the factors that drive private R&D expenditures, and those that could influence their impact on growth. In this research stream, we (Dominique Guellec and myself) investigated the joint impact of R&D subsidies, R&D tax credits and public R&D on economic growth and on business R&D. The findings illustrate, for the first time, that (i) the strong 'interaction' between policy tools, (ii) the 'non-linear' effect of R&D subsidies, where too low or too high subsidization rates have no or little impact on business R&D, and (iii) the role of 'institutional setting'.

Previous studies 'only' investigated single policy instruments (R&D subsidies, R&D tax credits, public R&D) at a time. In our investigations (Guellec and van Pottelsberghe, 2003 and 2004) we analyzed the simultaneous impact of several policy tools and show that they had strong interaction effects; hence they have to be better coordinated. For instance, fiscal incentives like R&D tax credits are run by the Ministry of Finance, whereas R&D subsidies are granted by Regional Government, and the two policies ultimately aim at fostering private R&D by reducing its cost. Very little coordination actually takes place, leading to inefficiencies in several countries. The non-linear effect underlined by our empirical analyses suggests that too low or too high R&D subsidies are not effective in stimulating private R&D, the optimal level ranging between 10 and 20%. Too low subsidization rates (like in Switzerland and Japan) do not constitute a sufficiently strong incentive to invest into R&D, whereas too high incentives are synonymous to a strong 'effet d'aubaine' (Norway, the UK and Spain during the period under investigation).

The institutional setting relates to the socioeconomic objectives of the subsidies. The empirical analysis leads to the conclusion that, at first hand, each dollar of R&D subsidy has a lower impact on growth than each dollar of private R&D. This result is confirmed by the evidence provided in the existing literature at that time. However, disentangling R&D subsidies according to their socioeconomic objectives mitigates this standard result. Indeed, it turns out that defense-related subsidies (primarily procurements, whose research results belong to the State) are associated with a lower impact by dollar invested, whereas other types of subsidies have a similar effect than private R&D.

These four early contributions to the scientific literature on R&D and growth were performed at the macroeconomic level. This level of aggregation is sometimes the only way to start addressing important political issues. But when data exist at the microeconomic level, further analytical contribution can be performed and other drivers of growth and innovation can be identified. Here, thanks to the very good end-year thesis of Florence Honoré, who performed her Ph.D. at University of Minnesota, and thanks to the contribution of Federico Munari, Professor at University of Bologna and expert in the field, we investigated whether corporate governance provisions could influence the propensity to invest in R&D.

More particularly, Honoré *et al.* (2015) empirically investigated whether corporate governance practices implemented to align shareholders' and managers' interests affect the resources firms devote to R&D. Two databases — one on governance ratings and one on R&D investment — were merged to obtain a multi-country, multi-sector sample of 177 European companies involved in R&D activities. The results suggest that limitations of anti-takeover devices and voting rights restrictions, a financial performance-based remuneration system for managers and a higher shareholders' consensus at the annual general assembly are all negatively correlated with R&D intensity. In other words, governance practices that are designed to respond to the short-term expectations of financial markets might prove to be detrimental to long-term R&D investments.

3.2. *On Patent Metrics and Patent Valuation Models (Part II and Part III)*

While working at the OECD/DSTI, I received in 1998 a raw database comprising detailed information on more than two millions patents filed at the EPO, since its creation in 1978. The project was to investigate the feasibility of creating a reliable methodology to count patents and produce patent-based indicators of innovation performance and of internationalization of technology for all OECD countries. Counting patents is far from being straightforward, as the reference date, reference firm, reference countries, patent families, and fractional counts must be considered. After several months of investigation Hélène Dernis, Dominique Guellec and myself fine-tuned a counting methodology and where able to produce the first series of patent counts per country and per industry, based on patent applications at the EPO. This first OECD release of patent statistics was later adopted by the World Intellectual Property Organization (WIPO), the United States Patent and Trademark Office (USPTO), and by the European Commission. The methodological paper was published jointly with Dominique Guellec and Hélène Dernis (2001) and became part of the state of the art for researchers relying on patent data and patent count methodologies.

The subsequent project was to create indicators of internationalization of technology. This led to a paper written jointly with Dominique Guellec (2001) which puts forward four indicators (based on co-invention, co-applicants, and cross-border ownership of domestic inventions, and cross-border ownership of foreign inventions) and investigates the factors that drive the degree of internationalization at the country level. Interestingly, when correcting for country size (small economies are logically more internationalized) and R&D intensity (the most R&D intensive economies collaborate more on a global scale), it turns out that Finland and Japan where the two economies that had the smallest propensity to collaborate internationally.

Counting the share of patents invented in a country and owned by foreign applicant gives an interesting insight of who owns technological innovations, but a limited one, as a company based in Germany might own patents invented in France, and be owned partly by UK investors. In order to gauge the extent to which company ownership would worsen the indicator of foreign ownership of technology, we teamed up with Professors Michele Cincera and Reinhilde Veugelers (2006) and identified the origin of ownership of the companies located in Belgium and which owned 80% of the patents invented in Belgium. Interestingly, when correcting for the ownership structure of these companies, it turns out that the large majority of patents invented in Belgium are actually ultimately owned by foreign investors.

After several years of fine-tuning the count methodology for research purposes, we developed a 'least biased' patent-based innovation indicators, based on priority filings at national patent offices (instead of the widely used USPTO, EPO, or Patent Cooperation Treaty (PCT) patent counts). This recent paper, jointly authored with several international colleagues (de Rassenfosse *et al.*, 2013), is nowadays frequently used as a key reference by research scholars. This methodology could not have been developed without the PATSTAT Database, put in place by the EPO, which includes patent application and patent processing data of about 40 patent offices in the world. This is an excellent example of how a public institution — the EPO — can deliver tools that are crucial for the advancement of research.

But the simple count of patents, especially priority filings, provides only a partial measure of innovation performance, as a vast majority of patents are never commercially exploited or effectively used by the industry. Therefore, companies and international institutions have tried to develop tools and indicators that improve patent-based metrics of innovation. This search for indicators of more 'valuable' patents has led to a fast growing literature. Authors generally chose a measure of patent value, and then regressed it against patent or applicant attributes, or value determinants. Once a value determinant or correlate is identified, it can then serve as a value metric itself.

One approach is to count the patents that are granted, as they have some legal exclusion power for their owners. In a joint paper with Dominique Guellec (2000), we showed that the grant rate is higher for large companies and patents that are subject to cross-border ownership. It is also higher for PCT applications. Interestingly, there are strong international difference in the grant rate of EPO patents, with the lowest grant rates observed for US and UK applicants, while a particularly high grant rate is observed for Japanese companies. These differences in grant rates witness strong heterogeneous propensities to file patents across countries: US or UK companies have a very high propensity to file patents, even for lower quality innovations.

Heterogeneous propensity to file patents for a given invention makes international comparisons of innovation performance difficult to implement. The number of patents filed in country A has not the same meaning as the number of patents in country B, hence the importance of understanding the drivers of the propensity to file patents. In Peeters and van Pottelsberghe (2006), we investigated the micro-level determinants of patent filings, with a database of more than 100 large firms operating in Belgium. The results show that taking into account the various dimensions of an innovation strategy turns out to approximate the patenting behavior of firms better than the traditional Schumpeterian hypotheses related to firm size and market power. Second, there is a positive relationship between the patent portfolio and a firm's innovation partnerships with external organizations — scientific institutions and competitors in particular. Process-oriented innovators patent less than product-oriented innovators and a stronger focus on basic and applied research is associated with a more active patenting behavior.

An alternative mechanism to correct for the high heterogeneity in the propensity to patent is to count patents differently, trying to take stock only of those that are associated with some significant economic value. In doing so the 'propensity effect' can be strongly mitigated by an improved indicator of innovation performance. Van Zeebroeck and van Pottelsberghe (2008) counted the patents according to their geographical scope (the number of countries in which they are enforced) and their duration (the number of years they are renewed). As these two dimensions are associated with costs (validation fees, renewal fees), the authors created the scope-year index, which identifies much better the share of high value patents than the mere count of patent filings or patent granted. This early paper on patent value captured 'only' two dimension of value (geographical scope and renewal) but not the extent to which subsequent innovation were built on the original patent application. These so-called forward patent citations are probably the most widely used patent-based value indicator in the literature. It witnesses the degree of involvement and innovation of a given patent. The 'grant' of a patent witnesses the legal validity of a patented invention and does not help much in identifying high value patents. Forward patent citations help identify innovations that attract further subsequent research, by its own team or by competitors.

The literature aiming either at measuring patent value or understanding its determinants is large and growing. van Zeebroeck and van Pottelsberghe (2011a, 2011b) searched for new value determinants, and the reliability and coherence of the vast existing literature in this field. The initial paper (2011a) contributes to the literature on the determinants of patent value in two ways. It first introduces a new potential class of value determinants in the form of filing strategies (including filing routes, drafting styles and divisional filings). Second, it provides empirical evidence based on a unique dataset of about 250,000 EPO patents that these strategies are consistently and positively associated with patent value, indicated by six different value metrics based on citations, families, renewals and oppositions. The contributions of the second paper are essentially twofold: it underlines significant inconsistencies across existing studies and it illustrates via a sensitivity analysis the strong dependencies of several 'classical' results to two main empirical dimensions, namely the choice of the dependent variables (indicator of patent value) and the sampling methodology. The new indicators of filing strategies put forward by van Zeebroeck and van Pottelsberghe (2011a) turn out to be the most robust and stable determinants of patent value.

3.3. *On Academic Patenting (Part IV)*

Two drivers made me enter into the research field on academic patenting. The first one is that this area of investigation was an important focus of international and national policy-makers. The OECD in the early 2000s was developing indicators of academic patenting, and these patents were considered as having a particularly high value for society, or at least with high economic potentials. The second reason is that I was asked by the ULB authorities to become advisor for knowledge transfer issues, and in this respect to chair the knowledge valuation committee of the ULB Technology Transfer Office (TTO). We therefore started with a state of the art of the literature, jointly with Nicolas van Zeebroeck, and I collaborated with Sarina Saragossi (2003) in order to start measuring and benchmarking Belgian universities. We illustrated the drastic increase in patenting by Belgian universities, mainly due to scientific advances in biotechnology, and to the willingness of policy-makers and universities to foster the contribution of academic research to regional development. We however noticed that many patents were invented in academic labs and owned by companies, which made the 'official' surveys misleading as the indicator could be heavily biased.

Academic patents are frequently considered to be associated with a high economic value on average, but there was no evidence on this assumption. We teamed up with Eleftherios Sapsalis (Ph.D. candidate) and Ran Navon (end-year student), to compare corporate and academic patents and test whether they have similar value distributions and share common determinants of value. The empirical results based on 400 biotech patents applied for by Belgian universities and firms lead to the following observations: (i) academic and corporate patent value distributions have similar levels of 'skewness'; (ii) the identification of the institutional origin of knowledge allows for an improved understanding of the value determinants; and (iii) star scientists file the most valued patents, a correlation that had obvious policy implications for regional government and university authorities. When excellent researchers are open to patenting, they should be supported to file patents.

These results to some extent confirmed the importance of the job I was assigned to by ULB authorities. But implementing effective and systematic knowledge transfer is actually more complicated than any policy-makers would imagine, nor corporate leaders. The TTOs are full of tensions, because all stakeholders are highly emotional. The scientists consider the patented invention as their own 'baby', investors want all access to technology and argue that licencing fees are always too high, the regional government wants to see many patents and spin-offs in their own territory (otherwise it is like a failure) and the administration is often accused of being responsible for any delay in the transfer process. Interestingly many stakeholders, those who always know better than the others, argued that there was a flaw in the governance of the process. I was open to such debate, but wanted to learn more before drawing too fast conclusions on what had to be done. We therefore teamed up with a team of TUM (Technische Universität München, in Schoen *et al.*, 2013) in order to contribute to the literature on academic patenting and the governance of technology transfer. We took into account the diversity of organizational models with a theoretical perspective, and then surveyed about 20 European TTOs. The paper presents a discussion on which combinations of four structural dimensions should yield viable configurations. Four main types of TTOs can be identified: (1) classical TTO; (2) autonomous TTO; (3) discipline-integrated Technology Transfer Alliance; and (4) discipline-specialized Technology Transfer Alliance. Second, the paper relies on 16 case studies of universities located in six European countries in order to address the pros and cons of the four types of TTOs. The paper provides both a conceptual understanding and an empirical overview of how universities organize their technology transfer and intellectual property management. The results illustrate the danger of using standard metrics to compare their performance or productivity, as policy-makers are frequently tempted to do. For instance, it is pointless to compare the productivity of a TTO that tackles only patent licenses with a more integrated TTO involved in public and private research contract management. These micro assessments of a very detailed aspect of universities' operation fail to grasp the interaction effects with other privately funded contract research or with scientific performance.

A more aggregate view of universities' entrepreneurial orientation is required to better understand its broad implication for the academic sector. Large-scale empirical research on antecedents of the entrepreneurial effectiveness of universities is however scarce. Van Looy *et al.* (2015) analyzed the extent to which scientific productivity affects entrepreneurial effectiveness, taking into account the size of universities and the presence of disciplines, as well as the R&D intensity of the regional business environment (BERD). With a dataset covering 105 European universities, we also assessed the occurrence of trade-offs between different transfer mechanisms (contract research, patenting and spin off activity). Our findings revealed that scientific productivity is positively associated with entrepreneurial effectiveness. Trade-offs between transfer mechanisms do not reveal themselves; on the contrary, contract research and spin off activities tend to facilitate each other.

3.4. *On the Role of Fees in Patent Systems (Part V)*

This research stream was inspired by my arrival at the EPO in October 2005, as Chief Economist. At the first board (where the directors of all national patent offices sit), I realized how budgetary issues were sensitive. After informal talks with the EPO leadership, I had the feeling that discussions on fees (application fees, examination fees, renewal fees, validation fees...) were actually side-stepped, relying on the dogmatic view by patent offices' leadership that fees did not influence the behavior of applicants. I therefore decided to test this 'implicit' hypothesis that patent fees did not influence firms' propensity to rely on the patent system. This question is complex as various types of fees are set by patent offices around the world. We started with stylized facts on the structure and typology of patent fees at patent offices and patent costs for applicants. Through several collaborative projects, we then investigated how various types of fees affected applicants' behavior.

My earlier investigation on patent fees and costs started in 2005 through a collaboration with Didier François, and end-year Master students (the paper was published in 2009). We were wondering whether the cost of patenting would affect the demand for patents. This early investigation focused on three patent systems (US, Europe, Japan), and led to the following conclusions: (i) for a proper international comparison, the size of the market and the average number of claims included in a patent must be accounted for; (ii) when the cost per claim per capita (the 3C-index) is considered, a negative linear relationship appears between the cost of patenting and the number of claims that is filed; (iii) after the grant of a patent by the EPO, the translation, validation and transaction costs induced by an effective protection in several European countries witness a highly fragmented and very expensive European market for intellectual property; (iv) for a patent designating 13 European countries, the 3C-index is about 10 (two) times higher than in the US (Japanese) system (for process and translation costs up to the grant); and (v) the European market being more than twice as large as the US market in terms of inhabitants, the 3C-index suggests that there would be a clear justification for higher nominal examination fees at the EPO, that would ensure the pursuit of a rigorous granting process.

The paper with Didier François provided a first formal international comparison of patent costs, with a comparable approach (the 3C-index, or the cost per claim per capita). It also graphically illustrated a potentially negative effect of fees on the demand for patents. It however lacked robustness, for three reasons: small sample, as we only had three observation points; incomplete assessment of costs, as we did not measure the non-patent fees costs, i.e., the cost related to intermediation or patent attorneys' services; and it was static, i.e., no time dimension. Several subsequent papers tackled these shortcomings. In a paper with Malwina Mejer (2010), we measured the relative importance of attorney costs across Europe, along with the impact of the London Protocol, which aimed at reducing the translation costs induced by the European Patent Convention (EPC).

A larger scale analysis was performed jointly with Gaetan de Rassenfosse (2007), who performed an internship at the EPO when I was Chief Economist. The paper investigates the role of the filing fees requested by the member states of the EPC. We provided first empirical evidence showing that the fee elasticity of the demand for priority applications is negative and significant. Given the strong variation in absolute fees and in fees per capita across countries, this result indicates a suboptimal treatment of inventors across European countries. This paper provided stronger evidence that fees do affect the behavior of applicants, but the time dimension was still missing. We pursued our collaboration with Gaetan de Rassenfosse (2012) and relied on a panel dataset of patent fees at the European (EPO), the US and the Japanese patent offices, ranging from 1980 to the early 2000s. Descriptive statistics show that fees have severely decreased at the EPO over the 1990s, converging towards the level of fees in the US and Japan. The estimation of dynamic panel data models suggests that the price elasticity of demand for patents is about -0.30.

Once a patent is granted by the EPO, the assignee must validate it, pay the translation costs, and pay the renewal fees to keep it in force in each country in which protection is sought. We investigated in Harhoff *et al.* (2009) the extent to which validation and renewal fees as well as translation costs affect the validation behavior of applicants. In this paper, we relied on a gravity model that aims at explaining patent flows between inventor and target countries within the European patent system. The results show that the size of countries, their wealth and the distance between their capital cities are significant determinants of patent flows. Validation fees and renewal fees further affect the validation behavior of applicants. Translation costs — which are difficult to measure — seem to have an impact as well. We concluded that the implementation of cost reducing policy interventions like the London Protocol would therefore induce a significant increase in the number of patents validated in each European country.

In all the papers that we performed on patent fees, we found that several types of fees (claim-based fees, application fees, renewal fees) and other patent-related costs (translation costs, attorneys costs) have a negative and significant impact on the propensity to file patents. The elasticity is however much lower than unity (inelastic), meaning that a fee increase is always associated with a less than proportional drop in applications, resulting in a significant increase of a patent office's budget. These fee elasticities are an important component in the current negotiations for the setting up of renewal fees for the forthcoming Unitary Patent. In the survey performed with Gaetan de de Rassenfosse (2013), we summarized the literature on patent fees, which provides grounds for both low and high application (or pre-grant) fees and renewal (or post-grant) fees, depending on the structural context and policy objectives. The paper also presents new stylized facts on patent fees of 30 patent offices worldwide, and the evolution of fees at the USPTO since its creation in the late 19th century. Application fees are generally lower than renewal fees, and renewal fees increase more than proportionally with patent age. In the US, patent fees have actually decreased in relative term, making access to patenting more affordable over the years.

3.5. *On the Design of Patent Systems (Part VI) and the Case of Europe (Part VII)*

After 26 months of professional experience as Chief Economist of the EPO, I had acquired a fair understanding of the motivations of all important stakeholders (examiners, patent attorneys, national patent offices, large firms, universities, EPO administration), and of how patent systems work. This in-depth understanding of patent systems, led Domique Guellec (former Chief Economist of the EPO, currently at the OECD) and myself to crystalize our knowledge into a book, entitled *The Economics of the European Patent System*, published by Oxford University Press. Several research questions are raised in this book. One topic that remained untouched by economists was related to the quality of the examination process. Historically this concept was associated with the scope of protection, its duration, or its geographical coverage, but it was not investigated through the lenses of the whole patent system (including appropriateness of the test of novelty, stringency of the inventiveness test, or transparency and public disclosure). In November 2007, I opted to leave the EPO and came back to ULB (and joined as well the Bruegel Think Tank) in order to be 100% free to perform research on quality in patent systems, a research topic that could not be pursued as being employed by a patent office. My main research hypothesis was that the quality of a patent system, as proxied by its transparency and stringency, is a key factor influencing the propensity to rely on patent systems.

In order to test this hypothesis, I had to perform an in-depth analysis of the systemic differences across patent systems, compute a synthetic index of quality, and test the extent to which quality would affect the demand for patents. The stepping-stone of this research was published in 2011 by the journal *Industrial and Corporate Change*. This in-depth qualitative analysis investigated three patent systems (US, Japan, and Europe). Quality was gauged through two main components — stringency and transparency — which were then assessed through dozens of operational design indicators. Graphical results suggested that quality had a strong impact on the relative demand for patents. We then created a simpler synthetic index including nine components and computed it for 42 countries. The quantitative analysis was published in *Research Policy* in 2013. The results confirmed that higher quality (more transparency and stringency) correlates with a lower propensity to patent.

It was then possible to integrate the results of my research on the role of fees and on the role of quality into a single theoretical model analyzing the two dimensions jointly. This exercise, which was performed jointly with Pierre Picard, tackles the issue from the lens of patent offices' governance. It presents detailed stylized facts and a theoretical model that illustrates how patent offices set fees and quality according to their ultimate industrial policy.

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A selection of 29 scientific articles are presented in this book, and they were selected within a larger number of publications in each of the research areas covered in the book. The exhaustive list of publications is listed below.

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001 - Exploring europe's r&d deficit relative to the us: differences in the rates of return to r&d of young leading r&d firms - Michele Cincera and Reinhilde Veugelers

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